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Remarks:
Amended claims in accordance with Rule 86 (2) EPC.

(54) Suspension arrangement, steering linkage arrangement and method for providing variable wheel track

(57) The invention relates to a method for wheel track adjustment for a steerable vehicle wheel arrangement, which arrangement includes a steering actuating mechanism, a controllable lever arm (20) having a pivot on a suspension control arm (10), which control arm is pivotably attached to the vehicle at a first end and is provided with a ball joint (11) that is pivotably attached to a wheel hub (2, 3) at a second end, and a pair of connecting rods (23, 24) pivotably connected to the lever arm (20) on opposite sides of the pivot of the lever arm (20) and to the wheel hub (2, 3) on opposite sides of the ball joint (11). Actuation of the lever arm (20) causes the connecting rods (23, 24) to displace the ball joint (11) a predetermined distance along an axis substantially transverse to a central longitudinal axis (X) of the vehicle, which distance is proportional to a vehicle wheel steering angle (α_I, α_O). The invention further relates to a suspension arrangement for a steerable vehicle wheel and a steering linkage arrangement therefore.

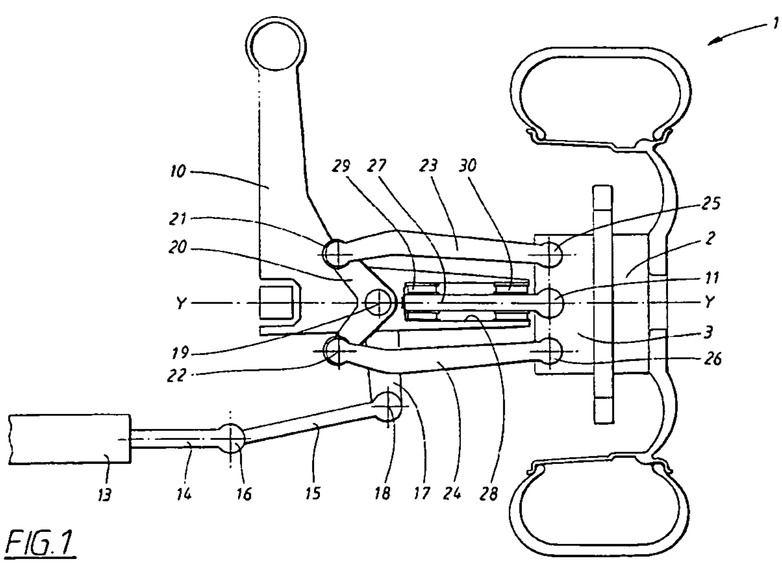

FIG.1

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Description

TECHNICAL FIELD

[0001] The invention relates to an arrangement and a method for wheel track adjustment for steerable wheels in a vehicle, in order to provide a turning circle radius reduction and improved cornering stability.

BACKGROUND ART

[0002] Modern passenger vehicles over a certain size are often provided with relatively large diameter wheels, which can give increased ride comfort and an improved fuel economy. At the same time there is a trend towards wider front drivetrain systems, usually in the form of transverse mounted engines, while the vehicle body has to remain as narrow as possible for aerodynamic reasons. As a result the available space for the wheels is decreased, which in turn decreases the maximum possible steering angle of the front wheels. There is also a trend towards vehicles with longer wheel bases, often, but not necessarily, combined with a transverse mounted engine. This arrangement increases the available interior passenger space and improves ride comfort. However, a long wheel base also increases the turning circle radius and may the problems caused by wheel size and drivetrain placement.

[0003] A known solution to the above problems is the use of four-wheel steering. However, this requires steerable rear wheels, which adds weight and complexity to the rear wheel suspension. Such a system also requires some form of computer control, as the steering behaviour of the rear wheels must be varied in both magnitude and direction depending on vehicle speed and other parameters.

[0004] A further known solution involves braking the inside front wheel when turning at low speed. This will reduce the turning circle radius, but at the cost of increased tire wear. The maximum steering angle is not affected by this solution. The arrangement will also require anti-locking brakes that can be computer controlled to brake individual wheels.

[0005] A solution that allows the pivot position of the wheels to be adjusted to avoid interference with body components is known from GB 2 110 173-A. This arrangement discloses a mechanical linkage connecting the steerable wheels in such a way that the wheels are prevented from coming into contact with the outer fairing of the vehicle. However, as this involves moving the pivots of the respective wheels inwards, the wheel track is reduced during turning and cornering. Especially when cornering, a reduced wheel track may affect the handling characteristics of the vehicle.

[0006] Hence, there exists a need for an arrangement that allows for increased steering angles combined with improved road handling

DISCLOSURE OF INVENTION

[0007] The problem of increasing the possible steering angles for steerable wheels while maintaining, or improving, the road handling of a vehicle is solved by a suspension arrangement as claimed in claim 1, a steering linkage arrangement as claimed in claim 11 and a method as claimed in claim 21.

[0008] The invention relates to a method for wheel track adjustment for a steerable vehicle wheel arrangement. The arrangement includes a steering actuator and a steering actuating mechanism for transferring steering movements from the steering actuator to a wheel hub. The steering actuating mechanism includes a controllable lever arm having a pivot on a suspension control arm, which control arm is pivotably attached to the vehicle at a first end and is provided with a ball joint that is pivotably attached to a wheel hub at a second end. A pair of connecting rods are pivotably connected to the lever arm on opposite sides of the pivot of the lever arm and to the wheel hub on opposite sides of the ball joint. The lever arm is controlled by a steering actuation mechanism and causes the connecting rods to displace the ball joint a predetermined distance along an axis substantially transverse to a central longitudinal axis of the vehicle, which distance is proportional to a vehicle wheel steering angle. The displacement of the ball joints increases as the steering angle is increased.

[0009] According to one embodiment, actuation of the lever arm causes the connecting rods to displace the ball joint in a direction away from the central longitudinal axis. In this way the vehicle wheel track is increased, in order to allow a increased steering angle and improve road handling during cornering.

[0010] According to a further embodiment, the ball joint of an inner wheel is displaced a greater distance than an outer wheel. During certain conditions, such as a turning operation at low speed, when the steering angle is relatively large or at maximum, the inner and outer wheels will be placed at different radii relative to an imaginary centre point. In order to reduce tyre wear it is advantageous to give the inner wheel a correspondingly greater steering angle.

[0011] A wheel track adjustment arrangement for a steerable vehicle wheel to be used according to the above method is part of both the suspension and the steering linkage of the vehicle. The suspension arrangement includes a first control arm having an inner end attached to the vehicle and pivotable around an axis substantially parallel to a longitudinal axis of the vehicle and an outer end pivotably connected to a wheel hub via a ball joint. The first control arm is preferably arranged as a lower control arm, whereby the suspension may be provided with a second, upper control arm attached between the vehicle and the wheel hub. A further suspension member may be attached between the vehicle and the wheel hub and arranged to suspend the vehicle and dampen vertical movement of said vehicle

wheel. This further suspension member may be a standard spiral spring and telescopic damper arrangement, or any other type of pneumatic or hydraulic damper. According to the invention, the suspension preferably includes a damper arrangement, while the second control arm is optional. The ball joint is displaceable a predetermined distance along an axis substantially transverse to the longitudinal direction of the vehicle, which distance is proportional to a vehicle wheel steering angle.

[0012] According to a further embodiment, the ball joint is arranged to be axially slidable relative to the control arm. According to an alternative embodiment, the ball joint is slidably attached to the control arm. In both cases, the ball joint and its attachment part may be secured to an outer surface of the control arm, or be placed in a cavity therein. The ball joint may also be attached directly onto the control arm, whereby the control arm itself may have a moving part, such as a telescoping section

[0013] The slidable attachment may be achieved by a number of different means. According to one embodiment the ball joint may be slidably suspended in one or more rubber or elastomeric bushings, surrounding the attachment part wholly or in part. The bushing or bushings may be attached onto the attachment part or to the inner surface of the cavity in the control arm. This arrangement allows the ball joint and its attachment part to slide freely in the transverse direction of the vehicle. At the same time the resilient bushings allow a degree of movement perpendicular to said direction.

[0014] The displacement of the ball joint is controlled by a pair of substantially parallel connecting rods pivotably attached to the vehicle wheel hub on either side of the ball joint. The connecting rods are pivotably attached to and controlled by a common lever arm that is pivotably attached to the control arm. In addition, the connecting rods have a length between their respective pivots that exceeds the distance between the pivot of the lever arm and the ball joint. Said lever arm is controlled by a vehicle steering gear actuator.

[0015] The combination of a resilient attachment and parallel connecting rods will contribute to an enhanced compliance of the suspension in the longitudinal direction of the vehicle. The resilient bushing will allow the ball joint and wheel hub to yield in the longitudinal direction when the tyre encounters an obstacle, such as a transverse tarmac edge. This will contribute to a more comfortable ride.

[0016] The movement of the ball joint is controlled by the connecting rods during actuation of the steering gear, so that the greatest displacement of the ball joint occurs at the maximum steering angle of the vehicle wheel. Preferably, the displacement of the ball joint causes an increase of the wheel track. The shape of the lever arm and the positions of the pivots of the connecting rods at the hub and the lever arm are symmetrically placed on either side of a vertical plane through the ball joint and the pivot of the lever arm.

[0017] According to a further embodiment, the ball joint of an inner wheel may be displaced a greater distance than an outer wheel. This is caused by the inner and outer wheels turning on different radii, as described above.

[0018] According to a preferred embodiment, this is achieved by means of a so-called Ackerman steering. This is a double-pivoting steering system where the outer ends of the steering arms are bent slightly inward so that when the vehicle is making a turn, the inside wheel will turn more sharply than the outer wheel. This is done to compensate for the greater distance the outside wheel must travel due to the difference in turning radii between the inner and the outer wheel. When the steering arms act on their respective lever arm, the above shape of said steering arms causes the inner wheel to turn through a greater steering angle than the outer wheel. The symmetrical arrangement of the lever arm and connecting rods will consequently displace the inner ball joint further out than the outer ball joint.

[0019] According to an alternative embodiment, the linkage described above can be made slightly asymmetrical. This can be achieved by altering the length of either of the connecting rods between their respective pivots. For instance, by extending the front connecting rods and their associated section of the lever arm, as seen in the main direction of travel of the vehicle, a suitable distance, the ball joint attached to the inner wheel would be pushed further out. Obviously, the same effect could be achieved by shortening the rear connecting rods and their associated section of the lever arm. An equal actuation of the lever arms on either side will then cause a greater steering angle for the inner wheel, accompanied by a corresponding greater displacement of the inner ball joint. This arrangement does not have to depend on the Ackerman steering principle to achieve unequal steering angles for the inner and outer wheels.

[0020] According to a further embodiment, the attachment points of the ball joint and the connecting rods ensures that the displacement of the ball joint also causes an adjustment of the camber angle of the vehicle wheel. The ball joint is preferably attached to a suspension control arm and is attached to the wheel hub below an attachment point for a further control arm or suspension member. If the hub is supported by the lower control arm and a dampening suspension member, an outward displacement of the ball joint will pivot the wheel hub around a pivot located at a pivotable attachment point for the upper end of the suspension member. If the hub is additionally supported by an upper control arm, an outward displacement of the ball joint will instead pivot the wheel hub around a pivot located at a pivotable attachment point for the inner end of the upper control arm. The increase in the camber angle is dependent on the distance between the ball joint and said attachment point of said further control arm or suspension member at the vehicle. In addition to the improved stability caused by the increased wheel track, this will have a

positive effect on the dynamic handling of the vehicle during cornering. Especially for the outer wheel, this negative camber will counteract the tendency towards positive camber caused by the rolling movement of the vehicle during cornering or turning.

[0021] As stated above, the wheel track adjustment arrangement to be used according to the above method is part of both the suspension and the steering linkage of the vehicle. The steering linkage arrangement includes an actuating mechanism, the above mentioned controllable lever arm having a pivot on the suspension control arm, which control arm is pivotably attached to the vehicle at a first end and is provided with a ball joint that is pivotably attached to a wheel hub at a second end, and where a pair of connecting rods are pivotably connected to the lever arm on opposite sides of the pivot and to the wheel hub on opposite sides of the ball joint. When the actuating mechanism is operated, the ball joint is displaced a predetermined distance along an axis substantially transverse to the longitudinal direction of the vehicle, which distance is proportional to a vehicle wheel steering angle. The lever arm is preferably positioned so that an axis substantially transverse to the longitudinal axis of the vehicle intersects both the ball joint and the pivot of the lever arm.

[0022] The actuating mechanism may comprise a steering arm actuated by a servo steering mechanism, which steering arm is then connected to the lever arm. Alternatively, the lever arm may be controlled by an electric or a hydraulic motor. Depending on factors such as the force required to turn the vehicle wheel and/or possible size limitations on the motor, said motor may actuate the lever arm directly or via a steering arm. The latter arrangement would be preferable for a steer-by-wire vehicle, where an electronic control unit could control each motor individually to achieve the desired effect.

[0023] In addition to the above embodiment using parallel connecting rods, a number of alternative embodiments are possible within the scope of the independent claims. Common for the embodiments described below is that the steering actuator acts on the wheel hub at a position horizontally displaced from the ball joint in a plane parallel to the wheel hub.

[0024] According to a first alternative embodiment the steering actuator can act on one end of a controllable lever arm having a pivot on the suspension control arm. Hence the controllable lever arm acts on a connecting rod pivotably connected between the other end of the lever arm, at on the opposite side of the pivot, and the wheel hub via the ball joint. In this embodiment the ball joint is mounted on the control arm by means of an elastic bushing that allows for both rotation and axial displacement of the ball joint at the end of the connecting rod. (Fig.5)

[0025] According to a second alternative embodiment the steering actuator can act on one end of an intermediate controllable lever arm having a pivot on the suspension control arm. The intermediate lever arm is provided with a teeth along a circular segment, in order to transmit a rotary motion to a gear wheel. A connecting rod is pivotably attached between the periphery of said gear wheel and the ball joint, so that rotation of the gear wheel causes a displacement of the ball joint. (Fig.6)

[0026] According to a third alternative embodiment the ball joint is attached to the end of a hydraulic actuator that controls the movement of the ball joint in response to the steering input from the driver. If the steering actuator is hydraulically operated, hydraulic pressure from said steering actuator may be used to actuate the hydraulic actuator attached to said ball joint. (Fig.7)

[0027] In the above examples the connecting rod or rods and/or the lever arm can alternatively be replaced by screw drives or hydraulic or pneumatic cylinders of equal or differing stroke, depending on the desired effect with respect to turning radius for opposing wheels. Such drives or cylinders may be attached to the control arm and the wheel hub at pivoting points corresponding to those of the connecting rod or rods, when the hub is aligned with the longitudinal axis of the vehicle. An electronic control means may be used for individual control of the respective devices.

[0028] The solution according to the invention allows the turning circle radius to be reduced by moving the pivots of the wheels away from interfering components, thereby allowing for larger steering angles. By allowing differentiated steering angles the turning circle radius can be further reduced. In addition, the displacement of the wheels, when turned, gives a wider wheel track for the steerable wheels, which improves handling of the vehicle during cornering. Hence the above solution has a positive effect on both the turning circle radius and the dynamic handling of the vehicle.

BRIEF DESCRIPTION OF DRAWINGS

[0029] In the following text, the invention will be described in detail with reference to the attached drawings. These drawings are used for illustration only and do not in any way limit the scope of the invention. In the drawings:

Figure 1	shows a plan view of a single driven front wheel provided with a suspension arrangement according to the invention;
Figure 2	shows a front view of a single driven front wheel provided with a suspension arrangement according to the invention;
Figure 3	shows a frontal view of a single driven front wheel provided with an alternative suspension arrangement;
Figure 4	shows a plan view of a suspension arrangement, with both wheels set at their respective maximum wheel angles.
Figure 5	shows a plan view of a first alternative embodiment of the suspension arrangement according to the invention;

Figure 6 shows a plan view of a second alternative embodiment of the suspension arrangement according to the invention;

Figure 7 shows a plan view of a third alternative embodiment of the suspension arrangement according to the invention;

Figure 8 shows a hydraulic servo cylinder for controlling the arrangement shown in Figure 7.

MODES FOR CARRYING OUT THE INVENTION

[0030] In the following text, the suspension arrangement for a single wheel is described unless otherwise indicated. Also, the terms "outer" and "inner" denotes positions of various features in a transverse direction relative to a central longitudinal axis of a vehicle.

[0031] Figure 1 shows a suspension arrangement comprising a wheel 1 including a tyre and a rim mounted on an outer part of a hub 2. The outer hub part 2 is rotatable, while an inner part 3 is non-rotatable. The outer hub part 2 is preferably, but not necessarily, provided with a brake disc 4 for co-operation with a brake caliper arrangement (not shown). The inner part of the hub 3 is provided with an attachment part 5 for a damper arrangement 6 of the McPherson type. This damper arrangement is pivotably attached both to the hub, at its lower end 6a, and to the vehicle, at its upper end 6b. The example shown illustrates a steerable, driven front wheel arrangement, whereby the inner part of the hub 3 is provided with an attachment 7 for a drive shaft 8. The outer part of the drive shaft 8 passes through said attachment 7 to drive the outer hub part 2, while the inner part of the drive shaft 8 is connected to the vehicle transmission (not shown) via a further attachment 9.

[0032] The inner part of the hub 3 is further connected to a suspension control arm 10 by means of a first ball joint 11. The control arm 10 is attached to the vehicle at an inner pivot 12 and is placed substantially parallel to the central longitudinal axis X of the vehicle. The outer pivot of the control arm 10 is the ball joint 11, which is attached to the inner part of the hub 3 at position below the rotary axis Y of the hub 2, 3 and in a vertical plane through said rotary axis Y. A substantially vertical axis Z through the first ball joint 11 constitutes the pivot of the steerable vehicle wheel.

[0033] The wheel is controlled by a steering gear arrangement that will be described with reference to Figure 2. This figure shows a front view of the embodiment of Figure 1 and where the drive shaft and damper have been removed for reasons of clarity. The hub is indicated in broken lines for the same reason. The steering gear arrangement comprises a servo cylinder 13 that when actuated causes a central rod 14 to act on a pair of steering linkages on either side of the vehicle. In the example shown, the rod acts on an intermediate steering rod 15, which is pivotably attached to the central rod 14 at an inner pivot 16 and to a steering arm 17 at an outer pivot 18. As can be seen from the figure, the central rod 14 is positioned transversely, while the steering arm 17 is positioned substantially parallel relative to the longitudinal axis of the vehicle. The steering rod 15 connecting the two is placed at angle in a direction outward and forward relative to the central longitudinal axis of the vehicle, thereby creating an Ackerman steering geometry. The steering arm 17 is pivotably attached to the control arm 10 at a first pivot 19 and controls the pivoting movement of a lever arm 20.

[0034] According to an alternative embodiment the servo cylinder 13 may be replaced by an electric or hydraulic motor acting on the steering arm 17 or directly on the lever arm 10.

[0035] The lever arm 20 is generally V-shaped with legs of substantially equal length and with its apex placed at said first pivot 19. Both legs extend horizontally away from the hub 2, 3 and are placed substantially symmetrical relative to a vertical plane through the axis Y of the wheel 1. The legs are provided with a second and third pivot 21 and 22 respectively, placed in front of and behind said vertical plane in the main direction of travel of the vehicle. A pair of connecting rods 23, 24 are connected between said second and third pivots 21, 22 and a pair of outer pivots 25, 26 on the inner hub part 3 on either side of the ball joint 11.

[0036] For a stationary vehicle with the steering gear arrangement in a neutral, non-actuated position, the connecting rods 23, 24 extend substantially parallel in a horizontal plane. The outer pivots 25, 26 of the connecting rods 23, 24 and the central ball joint 11 are preferably placed in the same horizontal plane and on an axis parallel to the longitudinal axis of the vehicle.

[0037] In the example shown, all pivots except the first pivot 19 of the lever arm 20 should allow pivoting movement in several axes, due to the movement of the suspension arrangement. In a preferred embodiment, all such joints are of the ball and socket type.

[0038] As can be seen from Figure 2, the ball joint 11 has an attachment part 27 in the form of a rod or bar. The attachment part 27 is slidably mounted in a cavity 28 in the part of the control arm 10 extending outwards to the hub 2, 3. The slidable mounting comprises a pair of generally cylindrical bushings 29, 30 placed adjacent the inner and outer ends of said attachment part 27. The bushings are preferably made from a suitable rubber or elastomeric material, and are clamped, glued or vulcanised onto the attachment part 27. In order to facilitate replacement, they are preferably clamped in place in the cavity 28. This arrangement allows movement of the ball joint 11 in the axial direction of the rod shaped attachment part 27, as well as a small movement in any transverse direction thereof due to the compressive properties of the bushings 29, 30. As the vehicle suspension is mainly arranged to absorb vertical movements of the vehicle wheel, this resilient mounting is particularly useful for absorbing small movements and shock loads on the vehicle wheel in the longitudinal direction of the vehicle.

[0039] Figure 3 shows an alternative suspension arrangement, wherein an upper, second control arm 10a is provided in addition to the lower, first control arm 10. This upper control arm 10a is pivotable attached between the vehicle and the inner part of the wheel hub 3 at a pair of inner and outer pivots 12a, 11a respectively. Apart from said upper control arm, the suspension arrangement is identical to that described in connection with Figure 2.

[0040] The function of the suspension and steering arrangement will be described with reference to Figure 4. In this figure an arrow indicates the main direction of travel of the vehicle. The axis X indicates the central longitudinal axis of the vehicle. The wheels 1 are shown at their maximum steering angles α_I, α_O at which positions they are closest to the inner sections of their respective wheel arches A_I, A_O. Actuation of the servo cylinder causes the steering linkage 14, 15, 17 to pivot the lever arm 20 and turn the respective wheel 1. As the wheels are turned, the ball joint 11 and the adjacent pivots 25, 26 remain aligned in a first plane perpendicular to the rotary axis of the wheel 1. However, although a similar, second plane through the pivots 21, 22 where the connecting rods 23, 24 are attached to the lever arm 20 will be substantially parallel to the latter plane, said second does not pass through the pivot 19 of the lever arm 20. A parallelogram created by the connecting rods 23, 24 will therefore have the ball joint 11 at a position half way between one pair of pivots. However, the distance between the ball joint 11 and its associated pivot 19 on the lever arm 20 is less than the distance between the ball joint 11 and an opposite, virtual point half way between the inner pivots 21,22 of the connecting rods 23,24. As soon as the lever arm 20 is pivoted in either direction, the movement transmitted to the hub 2, 3 by the connecting rods 23, 24 will cause the ball joint 11 and its attachment part 27 to be pulled outwards in the transverse direction of the vehicle. The ball joints on both sides of the vehicle will be displaced a small distance D_I, D_O from their equilibrium, or no-load positions in the slidable mountings 27, 29. The amount of movement is proportional to the respective lengths of and angle between the legs of the lever arm 20. The arrangement is preferably symmetrical on both sides of a vertical plane through the ball joint 11 and the pivot 19 of the lever arm 20.

[0041] According to a preferred embodiment, it is desirable to enable a somewhat larger wheel angle α_I for the inner wheel. During turning operations the inner and outer wheels will be placed at different radii relative to an imaginary centre point. In order to reduce tyre wear it is advantageous to give the inner wheel a greater steering angle α_I than the steering angle α_O of the outer wheel (α_I, > α_O). Preferably, this is achieved by means of the steering gear and steering rod geometry described above, using the Ackerman principle.

[0042] According to an alternative embodiment the differentiating effect between the inner and outer wheels is achieved by extending the front connecting rod 23, which also entails a modification of the length of the corresponding leg and/or angle between the legs of the lever arm 20.

[0043] For the current example the values of inner and outer steering wheel angles α_I, α_O are preferably selected within the ranges 35°< α_I <50° and 30°< α_O <40° respectively. The inner and outer displacements D_I, D_O of the respective ball joints are preferably selected within the ranges 8 mm > D_I >15 mm and 5 mm> D_I >12 mm respectively.

[0044] As can be seen from Figure 4, the inner sections of the wheel arches A_I, A_O have been enlarged to the rear of the wheel axis, in order to accommodate for the additional movement of the current inner wheel.

[0045] In both the above cases the vehicle track width is increased by the combined distances of the inner and the outer displacements (D_I +D_O). This contributes to an improvement in the dynamic handling of the vehicle during cornering.

[0046] According to a further preferred embodiment, the attachment points of the ball joint 11 and the connecting rods 23, 24 ensures that the displacement of the ball joint 11 also causes an increased camber angle β_I of the vehicle wheel (see Fig. 2). As the ball joint 11 is preferably attached to a suspension control arm 10 attached to the wheel hub 2, 3 below the axis Y of the wheel, a displacement of the ball joint 11 around a pivot located at a pivotable attachment point for the upper end 6b of the suspension member The outward movement of the ball joint 11 will increase the camber angle β_I of the vehicle wheel 1. This will contribute further to the improved handling characteristics during cornering.

[0047] For the embodiment of Figure 3, the pivot controlling the camber angle is instead located at the inner attachment point 12a of the upper, second control arm 10a. The outward movement of the ball joint 11 will increase the camber angle β_2 of the vehicle wheel 1. As the distance between the pivot 12a and the ball joint 11 is shorter (see Fig.2), a displacement of equal size of the ball joint 11 will result in a larger camber angle β_2 compared to the previous example.

[0048] The function of a first alternative embodiment of the suspension and steering arrangement will be described with reference to Figure 5. In this figure an arrow indicates the main direction of travel of the vehicle. The wheel 1 is shown at its maximum inner steering angle α_I. Actuation of the servo cylinder 13 causes the steering linkage 14, 15, 16 to act on a steering connecting rod 31 pivotably connected to a pivot 18 at the outer end of the steering linkage 15 and to a pivot 32 on the hub 2, 3, in order to turn the respective wheel 1. The pivot 18 at said outer end of the steering linkage 15 is further connected to one end of a lever arm 33 having a first pivot 34 attached to the control arm 10.

[0049] The lever arm 33 is generally V-shaped with legs of substantially equal length and with its apex placed at said first pivot 34. A first leg 35 is pivotably

connected to the pivot 18 on the steering linkage and a second leg 36 is pivotably connected to a pivot 37 at the inner end of a connecting rod 38. The outer end of said connecting rod 38 is connected to the wheel hub 2, 3 via the ball joint 11, which is attached to the outer end of the control arm 10 by means of an elastic bushing 39. For a stationary vehicle with the steering gear arrangement in a neutral, non-actuated position, the first leg 35 is positioned in the general direction of the longitudinal axis of the vehicle, while the second leg is positioned at substantially right angles to said axis X in a vertical plane for a transverse axis Y through the ball joint 11. In this position the connecting rod 38 extends substantially parallel to the second leg 36 and in the same vertical plane for the axis Y (see 37', 38'; indicated with dotted lines in Fig. 5). The steering connecting rod 31, the lever arm 33 and the connecting rod 38 are positioned substantially in the same horizontal plane.

[0050] When the steering linkage is actuated to displace the wheel 1 to its maximum inner steering angle α_I, then the lever arm 33 will be rotated an angle β_I about its pivot 34. A suitable angle of rotation to achieve the maximum angle of rotation can be $40° < \beta_I < 60°$, preferably around 50°. As the inner end of the connecting rod 38 moves along the arc described the pivot 37 the ball joint 11 will be simultaneously rotated and displaced in the bushing 39. The resilient properties of the bushing 39 are chosen to allow the outer end of the connecting rod 38 to be both rotated and displaced in the direction of the transverse Y-axis. However, movement in the longitudinal direction of the vehicle is limited and will in general only allow for shock absorption. This is preferably achieved by placing resilient elements in front of and behind the attachment point of the connecting rod, as shown in Figure 5. However, a single bushing with varying properties can also be used. Such a bushing would be include a relatively soft material in the inner and outer regions, and a relatively hard material in the front and rear regions of said bushing.

[0051] The total transverse displacement, in this case the inner displacement D_I, will be equal to the distance between the pivot 37' in the neutral position of the connecting rod 38' and the position of the rotated pivot 37 when projected onto the transverse axis Y.

[0052] A similar displacement will take place for the opposite, outer wheel. In this case the linkage will be a mirror image of the arrangement shown in Figure 5. The configuration of the steering linkage 14, 15, 16 will cause a smaller steering angle α_O for the outer wheel, as described above in connection with the Ackerman principle. Consequently the angle of rotation β_O of the lever arm 33 and the resulting displacement D_O will be correspondingly smaller.

[0053] The function of a second alternative embodiment of the suspension and steering arrangement will be described with reference to Figure 6. In this figure an arrow indicates the main direction of travel of the vehicle. The wheel 1 is shown at its maximum outer steering angle α_O. Actuation of the servo cylinder 13 causes the steering linkage 14, 15, 16 to act on a steering connecting rod 31 pivotably connected to a pivot 18 at the outer end of the steering linkage 15 and to a pivot 32 on the hub 2, 3, in order to turn the respective wheel 1. The pivot 18 at said outer end of the steering linkage 15 is further connected to one end of a lever arm 40 having a first pivot 41 attached to the control arm 10.

[0054] The lever arm 40 is generally Y-shaped having a first section, or leg 42 pivotably connected to the pivot 18 on the steering linkage. The first pivot 41 placed in a transitional area between the first section 42 and a second section 43 having the general shape of a sector of a circle 44. The circular end part 44 of the second section 43 comprises a toothed arc positioned at a fixed radius r from the first pivot 41. The toothed arc co-operates with a gear wheel 45 that is rotatable about a substantially vertical axis 46, positioned in a vertical plane for the transverse axis Y through the ball joint 11 at right angles to a longitudinal axis X of the vehicle. The inner end of a connecting rod 47 is pivotably attached to a second pivot 48 at the periphery of said gear wheel 45. The outer end of said connecting rod 47 is connected to the wheel hub 2, 3 via the ball joint 11, which is attached to the outer end of the control arm 10 by means of an elastic bushing 49. For a stationary vehicle with the steering gear arrangement in a neutral, non-actuated position, a central axis Z through the first and second sections 42, 43 is positioned in the general direction of the longitudinal axis of the vehicle. In this position the connecting rod 47 extends substantially at right angles to the central axis Z, in the said vertical plane for the axis Y (see 47'; indicated with dotted lines in Fig. 6). The steering connecting rod 31, the lever arm 40 and the connecting rod 47 are positioned substantially in the same horizontal plane.

[0055] When the steering linkage is actuated to displace the wheel 1 to its maximum outer steering angle α_O, then the lever arm 40 will be rotated an angle β_O about its pivot 34. This angle of rotation β_O is selected to achieve a maximum rotation of 90° for the gear wheel 45. The radius r of the end part 44 of the second section 43 and the diameter of the gear wheel 45 may be varied to give this end result.. As shown in Figure 6, rotation of the gear wheel 45 moves the inner pivot 48 and the connecting rod 47 from a neutral position (see 47'; indicated with dotted lines) to an active position, whereby the ball joint is displaced outwards a distance D_O. The maximum displacement possible by means of a quarter revolution of the gear wheel is the distance the axis 46 of the gear wheel and the inner pivot 48 of the connecting rod 47, which corresponds to the inner displacement D_I. The Ackerman-principle as described above will give a correspondingly smaller outer displacement D_O, due to the smaller outer steering angle a_O. As the inner end of the connecting rod 47 is moved by the gear wheel , the ball joint 11 will be simultaneously rotated and displaced in a bushing 49 between the connecting rod 47 and the

control arm 10. The resilient properties of the bushing 49 are chosen to allow the outer end of the connecting rod 47 to be both rotated and displaced in the direction of the transverse Y-axis. However, movement in the longitudinal direction of the vehicle is limited and will in general only allow for shock absorption. This is preferably achieved by placing resilient elements in front of and behind the attachment point of the connecting rod 47, as shown in Figure 6. As stated above, alternative embodiments of said bushing 49 are also possible.

[0056] The function of a third alternative embodiment of the suspension and steering arrangement will be described with reference to Figure 7. In this figure an arrow indicates the main direction of travel of the vehicle. The wheel 1 is shown at its maximum inner steering angle α_I. Actuation of the servo cylinder 13 causes the steering linkage 14, 15, 16 to act on a steering connecting rod 31 pivotably connected to a pivot 18 at the outer end of the steering linkage 15 and to a pivot 32 on the hub 2, 3, in order to turn the respective wheel 1. The schematically illustrated main servo cylinder 13 is provided with a first chamber 50, a second chamber 51 and a piston 52 separating said chambers 50, 51. The main servo cylinder 13 is connected to an auxiliary servo cylinder 53 that controls the displacement of a connecting rod 54. Said first chamber 50 in the main servo cylinder is connected by a first conduit 55 to a first auxiliary chamber 56 in the auxiliary servo cylinder. Similarly, the second chamber 51 in the main servo cylinder is connected by a second conduit 57 to a second auxiliary chamber 58 in the auxiliary servo cylinder. The first and second chambers 56, 58 in the auxiliary servo cylinder are separated by a piston 59, attached to the inner end of the connecting rod 54. The outer end of the connecting rod is attached to the ball joint 11, which is pivotably connected to the hub 2, 3 of the wheel 1 and attached to the outer end of the control arm 10 by means of an elastic bushing 60. The inner end 61 of the auxiliary servo cylinder 53 is attached to the inner end of the control arm 10 by means of a resilient mounting 62. This resilient mounting 62 is arranged to absorb vibrations caused by longitudinal and transverse movements of the connecting rod 54. However, the mounting 62 should not yield under forces induced by actuation of the auxiliary servo cylinder 53. The general design, as well as various embodiments, of the elastic bushing 60 has been described above.

[0057] When the main servo cylinder is actuated to turn the wheel to its maximum inner steering angle α_I, as shown in Figure 7, the auxiliary servo cylinder is automatically actuated. The piston 52 is displaced with the steering linkage as a piston rod 63 in the main servo cylinder 13 is actuated. The piston 52 acts on the substantially incompressible fluid in the first cylinder 50, forcing said fluid through the first conduit 55 into the first auxiliary chamber 56. The displaced fluid acts on the piston 59, whereby the conneting rod 54 is moved outward a predetermined distance, or inner displacement. At the same time, fluid from the second auxiliary chamber 58, displaced by the piston 59, is drained through the second conduit 57 into the second chamber 51 in the servo cylinder. When the wheel is returned to its neutral, non-actuated position, both pistons 52, 59 are returned to their respective initial positions, where the pressure in the fluid is equal on both sides of the respective piston.

[0058] The dimensions of the second servo cylinder are selected to give a desired displacement of the connecting rod on both sides of the vehicle. As the operation of the auxiliary servo cylinder and its connecting rod is dependent on the pressure of the displaced fluid in the main servo cylinder, there is no mechanical connection between the steering linkage and the connecting rod. Hence it is possible to design the suspension arrangement for equal inner and outer displacement D_I, D_O.

[0059] Figure 8 shows an alternative embodiment of the hydraulic circuits in a hydraulically operated arrangement. In this figure, the auxiliary cylinders 53, 53' are identical to the cylinder described in Figure 7 and are provided with the same reference numerals. The only difference being that the second conduits 57, 57' have been joined and connected to a common second chamber 64, or drain by a conduit 65. Figure 8 shows the arrangement in its neutral non-actuated position. As the arrangement is identical but reversed on either side of a centre line through said common second chamber 64, only one side of the arrangement will be described below.

[0060] In Figure 8 the main servo cylinder has a through piston rod 66 provided with a first and second step 67, 68 defining a section having a reduced diameter on either side of a central section 69 in a main cavity of the servo cylinder. Located in contact with the first step 67, that faces away from the central section 69, is a first piston 70 that is slidable relative to the reduced diameter section. This first piston 70 has a substantially cylindrical shape with a radially extending section 71, 72 at either end. The first radially extending section 71 is spring loaded towards the first step 67 adjacent the central section by means of a spring 73 located between said first radial section 71 and a first radial step 74 in the inner cavity of the servo cylinder. Enclosed between the first radial section 71 and its opposed mirror image 71' at the other side of the central section is the said second chamber 64 that is connected to the common conduit 65 and acts as a drain for the auxiliary cylinders. The second radially extending section 72 extends into a further cavity of the servo cylinder and is in contact with a second radial step 75 in the inner cavity, facing away from the central section 69. Opposing the second radially extending section 72 is a separate piston 76 slidable relative to the reduced diameter section and in contact with a third radial step 77 in the inner cavity, facing towards the central section 69. Enclosed between the second radial section 72 and the separate piston 76 is a chamber 78 connected through the conduit 55 to the first chamber

56 of the auxiliary cylinder.

[0061] In operation, actuation of the servo cylinder 13 causes a displacement of the through piston rod 66, for instance to the left in Figure 8. The first step 67 on the piston rod 66 will displace the first piston 70 to the left against the force of the spring 73. This displaced the second radial section 72 towards the separate piston 76 thereby compressing the fluid in the chamber 78 and forcing it into the first chamber 56 of the auxiliary cylinder. Simultaneously, at the opposite side of the central section 69, the second step 68' on the piston rod 66 will displace the separate piston 76' to the left. The second radially extending section 72' of the corresponding first piston will be held stationary by the second step 77' in the internal cavity. Hence, the separate piston 76' will compress the fluid in the chamber 78', forcing it into the first chamber 56' of the auxiliary cylinder. The lower half of Figure 8 shows the rod 66 and the pistons 70, 70' and 76, 76' in their displaced positions.

[0062] The compression the fluid in the chambers 56, 56' causes the connecting rods 54, 54' to be displaced outwards and increase the wheel track. Fluid displaced by the pistons 59, 59' will flow from the second chambers 58, 58' and through the respective conduits 57, 57' and common conduit 65 into the common drain chamber 64.

[0063] The arrangement according to the invention is not limited to the above embodiments, but may be varied within the scope of the appended claims.

Claims

1. Method for wheel track adjustment for a steerable vehicle wheel arrangement, which arrangement includes a steering actuator, a steering actuating mechanism for transferring steering movements from the steering actuator and a wheel hub (2, 3), a control arm (10) pivotably attached to the vehicle at a first end and is provided with a ball joint (11) that is pivotably attached to the wheel hub (2, 3) at a second end, **characterized in that** actuation of the steering actuating mechanism (13, 14, 16) causes a displacement of the ball joint (11) a predetermined distance along an axis substantially transverse to a central longitudinal axis (X) of the vehicle, which distance is proportional to a vehicle wheel steering angle (α_I, α_O).

2. Method according to claim 1, **characterized in that** the displacement of the ball joint (11) increases as the steering angle (α_I, α_O) is increased.

3. Method according to claim 1, **characterized in that** actuation of the steering actuator causes a displacement of the ball joint (11) in a direction away from the central longitudinal axis (X).

4. Method according to claim 1, **characterized in that** the steering actuator acts on a controllable lever arm (20, 33, 40) rotatable about a pivot (19, 34, 41) on the suspension control arm (10).

5. Method according to claim 4, **characterized in that** the controllable lever arm (20) acts on a pair of connecting rods (23, 24) pivotably connected to the lever arm (20) on opposite sides of the pivot (19) of the lever arm (20) and to the wheel hub (2, 3) on opposite sides of the ball joint (11).

6. Method according to claim 1, **characterized in that** the steering actuator acts on one end of a controllable lever arm (20, 33, 40) having a pivot (19, 34, 41) on the suspension control arm (10).

7. Method according to claim 6, **characterized in that** the controllable lever arm (20) acts on at least one connecting rod (23, 24) pivotably connected between the lever arm (20) on the opposite side of the pivot (19) of the lever arm (20) and to the ball joint (11).

8. Method according to claim 6, **characterized in that** the steering actuator acts on a steering connecting rod the wheel hub (2, 3) at a position horizontally displaced from the ball joint (11).

9. Method according to claim 8, **characterized in that** the steering connecting rod acts on the wheel hub at a position horizontally displaced from the ball joint (11).

10. Method according to claim 9, **characterized in that** the lever arm (40) transmits a rotary motion to a gear wheel (45) to actuate a connecting rod (47) attached to said ball joint (11).

11. Method according to claim 9, **characterized in that** the steering actuator is hydraulically operated and that hydraulic pressure from said steering actuator is used to actuate a hydraulic actuator (53) attached to said ball joint (11).

12. Method according to any of the above claims, **characterized in that** the displacement of the ball joint (11) also causes an increased negative camber angle (β).

13. Method according to claim 2, **characterized in that**, when the steering linkage is actuated, the ball joint (11) of an inner wheel is displaced a greater distance than that of an outer wheel.

14. Suspension arrangement for a steerable vehicle wheel which suspension includes a first control arm (10) having an inner end attached to the vehicle and pivotable around an axis substantially parallel to a

longitudinal axis (X) of the vehicle and an outer end pivotably connected to a wheel hub (2, 3) via a ball joint (11), and a further suspension member (6) attached between the vehicle and the wheel hub (2, 3) and arranged to absorb and dampen vertical movement of said vehicle wheel, **characterized in that** the ball joint (11) is arranged to be displaced a predetermined distance along an axis substantially transverse to the longitudinal axis (X) of the vehicle, which distance is proportional to a vehicle wheel steering angle (α_I, α_O).

15. Suspension arrangement according to claim 14, **characterized in that** the ball joint (11) is arranged to be axially slidable relative to the control arm (10).

16. Suspension arrangement according to claim 14, **characterized in that** the greatest displacement of the ball joint (11) occurs at maximum steering angle (α_I, α_O).

17. Suspension arrangement according to claim 14, **characterized in that**, during a turning operation, the ball joint (11) of an inner wheel is arranged to be displaced a greater distance than that of an outer wheel.

18. Suspension arrangement according to claim 14, **characterized in that** the displacement of the ball joint (11) is arranged to increase the wheel track of the steerable wheels.

19. Suspension arrangement according to claim 14, **characterized in that** the displacement of the ball joint (11) is arranged to cause a negative vehicle wheel camber angle (β).

20. Suspension arrangement according to claim 14, **characterized in that** the displacement of the ball joint (11) is controlled by a controllable lever arm (20, 33, 40) that is rotated about a pivot (19, 34, 41) on the suspension control arm (10).

21. Suspension arrangement according to claim 20, **characterized in that** either end of said lever arm is connected to a pair of connecting rods (23, 24) pivotably attached to the wheel hub (2, 3) on either side of the ball joint (11).

22. Suspension arrangement according to claim 21, **characterized in that** the connecting rods (23, 24) have a length between their respective pivots that exceeds the distance between the pivot of the lever arm (20) and the ball joint (11).

23. Suspension arrangement according to claim 22, **characterized in that** the ball joint (11) is arranged to be axially slidable in the outer end of the control arm (10).

24. Suspension arrangement according to claim 20, **characterized in that** one end of said lever arm is connected to a connecting rod (23, 24) pivotably attached to the wheel hub (2, 3) by means of the ball joint (11).

25. Suspension arrangement according to claim 24, **characterized in that** the end of the connecting rod attached to the wheel hub (2, 3) is resiliently mounted on the suspension arm (10).

26. Suspension arrangement according to claim 24, **characterized in that** the lever arm (40) transmits a rotary motion to a gear wheel (45) to actuate a connecting rod (47) attached to said ball joint (11).

27. Suspension arrangement according to claim 20, **characterized in that** the lever arm (20) is controlled by a vehicle steering gear actuator (14).

28. Suspension arrangement according to claim 14, **characterized in that** the displacement of the ball joint (11) is controlled by a hydraulic actuator (53) mounted on the suspension control arm (10).

29. Suspension arrangement according to claim 28, **characterized in that** the hydraulic actuator is arranged to be operated by hydraulic pressure from a servo steering unit.

30. Steering linkage arrangement for controlling a vehicle wheel, which arrangement includes a steering actuator, a steering actuating mechanism for transferring steering movements from the steering actuator and a wheel hub (2, 3), a control arm (10) pivotably attached to the vehicle at a first end and is provided with a ball joint (11) that is pivotably attached to the wheel hub (2, 3) at a second end, **characterized in that** the ball joint (11) is displaceable a predetermined distance along an axis substantially transverse to the longitudinal axis (X) of the vehicle, which distance is proportional to a vehicle wheel steering angle (α_I, α_O).

31. Steering linkage arrangement according to claim 30, **characterized in that** the greatest displacement of the ball joint (11) occurs at maximum steering angle (α_I, α_O).

32. Steering linkage arrangement according to claim 31, **characterized in that**, when the steering linkage is actuated, the ball joint (11) of an inner wheel is displaced a greater distance than that of an outer wheel.

33. Steering linkage arrangement according to claim

30, **characterized in that** the displacement of the ball joint (11) is arranged to increase the wheel track of the steerable wheels.

34. Steering linkage arrangement according to claim 33, **characterized in that** the displacement of the ball joint (11) is arranged to cause a negative vehicle wheel camber angle (β).

35. Steering linkage arrangement according to claim 30, **characterized in that** the steering actuator is arranged to act on a controllable lever arm (20, 33, 40) rotatable about a pivot (19, 34, 41) on the suspension control arm (10).

36. Steering linkage arrangement according to claim 35, **characterized in that** the controllable lever arm (20) is arranged to act on a pair of connecting rods (23, 24) pivotably connected to the lever arm (20) on opposite sides of the pivot (19) of the lever arm (20) and to the wheel hub (2, 3) on opposite sides of the ball joint (11).

37. Steering linkage arrangement according to claim 36, **characterized in that** the connecting rods (23, 24) have a length between their respective pivots that exceeds the distance between the pivot of the lever arm (20) and the ball joint (11).

38. Steering linkage arrangement according to claim 37, **characterized in that** the transverse axis intersecting the ball joint (11) also intersects the pivot of the lever arm (20).

39. Steering linkage arrangement according to claim 30, **characterized in that** the steering actuator is arranged to act on one end of a controllable lever arm (20, 33, 40) having a pivot (19, 34, 41) on the suspension control arm (10).

40. Steering linkage arrangement according to claim 39, **characterized in that** the controllable lever arm (20) is arranged to act on at least one connecting rod (23, 24) pivotably connected to the lever arm (20) on the opposite side of the pivot (19) of the lever arm (20) and on the wheel hub (2, 3) via the ball joint (11).

41. Steering linkage arrangement according to claim 35, **characterized in that** the steering actuator is arranged to act on a steering connecting rod the wheel hub (2, 3 at a position horizontally displaced from the ball joint (11).

42. Steering linkage arrangement according to claim 41, **characterized in that** the steering connecting rod is attached to the wheel hub at a position horizontally displaced from the ball joint (11).

43. Steering linkage arrangement according to claim 42, **characterized in that** the lever arm (40) is arranged to transmit a rotary motion to a gear wheel (45) to actuate a connecting rod (47) attached to said ball joint (11).

44. Steering linkage arrangement according to claim 42, **characterized in that** the steering actuator is hydraulically operated and that hydraulic pressure from said steering actuator is arranged to actuate a hydraulic actuator (53) attached to said ball joint (11).

Amended claims in accordance with Rule 86(2) EPC.

1. Method for wheel track adjustment for a steerable vehicle wheel arrangement, which arrangement includes a steering actuator, a steering actuating mechanism for transferring steering movements from the steering actuator and a wheel hub (2, 3), a control arm (10) pivotably attached to the vehicle at a first end and is provided with a ball joint (11) that is pivotably attached to the wheel hub (2, 3) at a second end, **characterized in that** actuation of the steering actuating mechanism (13, 14, 16) causes a displacement of the ball joint (11) a predetermined distance along an axis substantially transverse to a central longitudinal axis (X) of the vehicle, which distance is proportional to a vehicle wheel steering angle (α_I, α_O), and that the steering actuator acts on a controllable lever arm (20, 33, 40) rotatable about a pivot (19, 34, 41) on the suspension control arm (10), wherein the controllable lever arm (20) acts on a pair of connecting rods (23, 24) pivotably connected to the lever arm (20) on opposite sides of the pivot (19) of the lever arm (20) and to the wheel hub (2,3) on opposite sides of the ball joint (11).

2. Method according to claim 1, **characterized in that** the displacement of the ball joint (11) increases as the steering angle (α_I, α_O) is increased.

3. Method according to claim 1, **characterized in that** actuation of the steering actuator causes a displacement of the ball joint (11) in a direction away from the central longitudinal axis (X).

4. Method according to claim 1, **characterized in that** the steering actuator acts on one end of a controllable lever arm (20, 33, 40) having a pivot (19, 34, 41) on the suspension control arm (10).

5. Method according to claim 4, **characterized in that** the controllable lever arm (20) acts on a pair of connecting rods (23, 24) pivotably connected between the lever arm (20) on opposite sides of the

pivot (19) of the lever arm (20) and to the ball joint (11).

6. Method according to claim 4, **characterized in that** the steering actuator acts on a steering connecting rod the wheel hub (2, 3,) at a position horizontally displaced from the ball joint (11).

7. Method according to claim 6, **characterized in that** the steering connecting rod acts on the wheel hub at a position horizontally displaced from the ball joint (11).

8. Method according to claim 7, **characterized in that** the lever arm (40) transmits a rotary motion to a gear wheel (45) to actuate a connecting rod (47) attached to said ball joint (11).

9. Method according to claim 8, **characterized in that** the steering actuator is hydraulically operated and that hydraulic pressure from said steering actuator is used to actuate a hydraulic actuator (53) attached to said ball joint (11).

10. Method according to any of the above claim , **characterized in that** the displacements of the ball joint (11) also causes an icreased negative camber angle (β).

11. Method according to claim 2, **characterized in that**, when the steering linkage is actuated, the ball joint (11) of an inner wheel is displaced a greater distance than that of an outer wheel.

12. Suspension arrangement for wheel track adjustement of a steerable vehicle wheel which suspension includes a first control arm (10) having an inner end attached to the vehicle and pivotable around an axis substantially parallel to a longitudinal axis (X) of the vehicle and an outer end pivotably connected to a wheel hub (2, 3) via a ball joint (11), and a further suspension member (6) attached between the vehicle and the wheel hub (2, 3) and arranged to absorb and dampen vertical movement of said vehicle wheel, **characterized in that** the ball joint (11) is arranged to be displaced a predetermined distance along an axis substantially transverse to the longitudinal axis (X) of the vehicle, which distance is proportional to a vehicle wheel steering angle (α_I, α_O), and that the displacement of the ball joint (11) is controlled by a controllable lever arm (20, 33, 40) that is rotated about a pivot (19, 34, 41) on the suspension control arm (10), wherein either end of said lever arm is connected to a pair of connecting rods (23, 24) pivotably attached to the wheel hub (2, 3) on either side of the ball joint (11).

13. Suspension arrangement according to claim 12, **characterized in that** the ball joint (11) is arranged to be axially slidable relative to the control arm (10).

14. Suspension arrangement according to claim 12, **characterized in that** the greatest displacement of the ball joint (11) occurs at maximum steering angle (α_I, α_O).

15. Suspension arrangement according to claim 12, **characterized in that** during a turning operation, the ball joint (11) of a inner wheel is arranged to be displaced a greater distance than that of an outer wheel.

16. Suspension arrangement according to claim 12, **characterized in that** the displacement of the ball joint (11) is arranged to increase the wheel track of the steerable wheels.

17. Suspension arrangement according to claim 12, **characterized in that** the displacement of the ball joint (11) is arranged to cause a negative vehicle wheel camber angle (β).

18. Suspension arrangement according to claim 12, **characterized in that** the connecting rods (23, 24) have a lengh between their respective pivots that exceeds the distance between the pivot of the lever arm (20) and the ball joint (11).

19. Suspension arrangement according to claim 18, **characterized in that** the ball joint (11) is arranged to be axially slidable in the outer end of the control arm (10).

20. Suspension arrangement according to claim 18, **characterized in that** one end of said lever arm is connected to a connecting rod (23, 24) pivotably attached to the wheel hub (2, 3) by means of the ball joint (11).

21. Suspension arrangement according to claim 20, **characterized in that** the end of the connecting rod attached to the wheel hub (2, 3) is resiliently mounted on the suspension arm (10).

22. Suspension arrangement according to claim 20, **characterized in that** the lever arm (40) transmits a rotary motion to a gear wheel(45) to actuate a connecting rod (47) attached to said ball joint (11).

23. Suspension arrangement according to claim 18, **characterized in that** the lever arm (20) is controlled by a vehicle steering gear actuator (14).

24. Suspension arrangement according to claim 12, **characterized in that** the displacement of the ball joint (11) is controlled by a hydraulic actuator (53)

mounted on the suspension control arm (10).

25. Suspension arrangement according to claim 24, **characterized in that** the hydraulic actuator is arranged to be operated by hydraulic pressure from a servo steering unit.

26. Steering linkage arrangement for wheel track adjustement of a vehicle wheel, which arrangement includes a steering actuator, a steering actuating mechanism for transferring steering movements from the steering actuator and a wheel hub (2, 3), a control arm (10) pivotably attached to the vehicle at a first end and is provided with a ball joint (11) that is pivotably attached to the wheel hub (2, 3) at a second end, **characterized in that** the ball joint (11) is displaceable a predetermined distance along an axis substantially transverse to the longitudinal axis (X) of the vehicle, which distance is proportional to a vehicle wheel steering angle (α_I, α_O), and that the steering actuator is arranged to act on one of a controllable lever arm (20, 33, 40) having a pivot (19, 34, 41) on the suspension control arm (10), wherein the controllable lever arm (20) is arranged to act on at least one connecting rod (23, 24) pivotably connected to the lever arm (20) on the opposite side of the pivot (19) of the lever arm (20) and on the wheel hub (2, 3) via the ball joint (11).

27. Steering linkage arrangement according to claim 26, **characterized in that** the greatest displacement of the ball joint (11) occurs at maximum steering angle (α_I, α_O).

28. Steering linkage arrangement according to claim 27, **characterized in that**, when the steering linkage is actuated, the ball joint (11) of an inner wheel is displaced a greater distance than that of an outer wheel.

29. Steering linkage arrangement according to claim 26, **characterized in that** the displacement of the ball joint (11) is arranged to increase the wheel track of the steerable wheels.

30. Steering linkage arrangement according to claim 29, **characterized in that** the displacement of the ball joint (11) is arranged to cause a negative vehicle wheel camber angle (β).

31. Steering linkage arrangement according to claim 26, **characterized in that** the steering actuator is arranged to act on a controllable lever arm (20, 33, 40) rotatable about a pivot (19, 34, 41) on the suspension control arm (10).

32. Steering linkage arrangement according to claim 31, **characterized in that** the controllable lever arm (20) is arranged to act on a pair of connecting rods (23, 24) pivotably connected to the lever arm (20) on opposite sides of the pivot (19) of the lever arm (20) and to the wheel hub (2, 3) on opposite sides of the ball joint (11).

33. Steering linkage arrangement according to claim 32, **characterized in that** the connecting rods (23, 24) have a length between their respective pivots that exceeds the distance between the pivot of the lever arm (20) and the ball joint (11).

34. Steering linkage arrangement according to claim 33, **characterized in that** the transverse axis intersecting the ball joint (11) also intersects the pivot of the lever arm (20).

35. Steering linkage arrangement according to claim 31, **characterized in that** the steering actuator is arranged to act on a steering connecting rod the wheel hub (2, 3 at a position horizontally displaced from the ball joint (11).

36. Steering linkage arrangement according to claim 26, **characterized in that** the steering connecting rod is attached to the wheel hub at the position horizontally displaced from the ball joint (11).

37. Steering linkage arrangement according to claim 36, **characterized in that** the lever arm (40) is arranged to transmit a totary motion to a gear wheel (45) to actuate a connecting rod (47) attached to said ball joint (11).

38. Steering linkage arrangement according to claim 36 , **characterized in that** the steering actuator is hydraulically operated and that hydraulic pressure from said steering actuator is arranged to actuate a hydraulic actuator (53) attached to said ball joint (11).

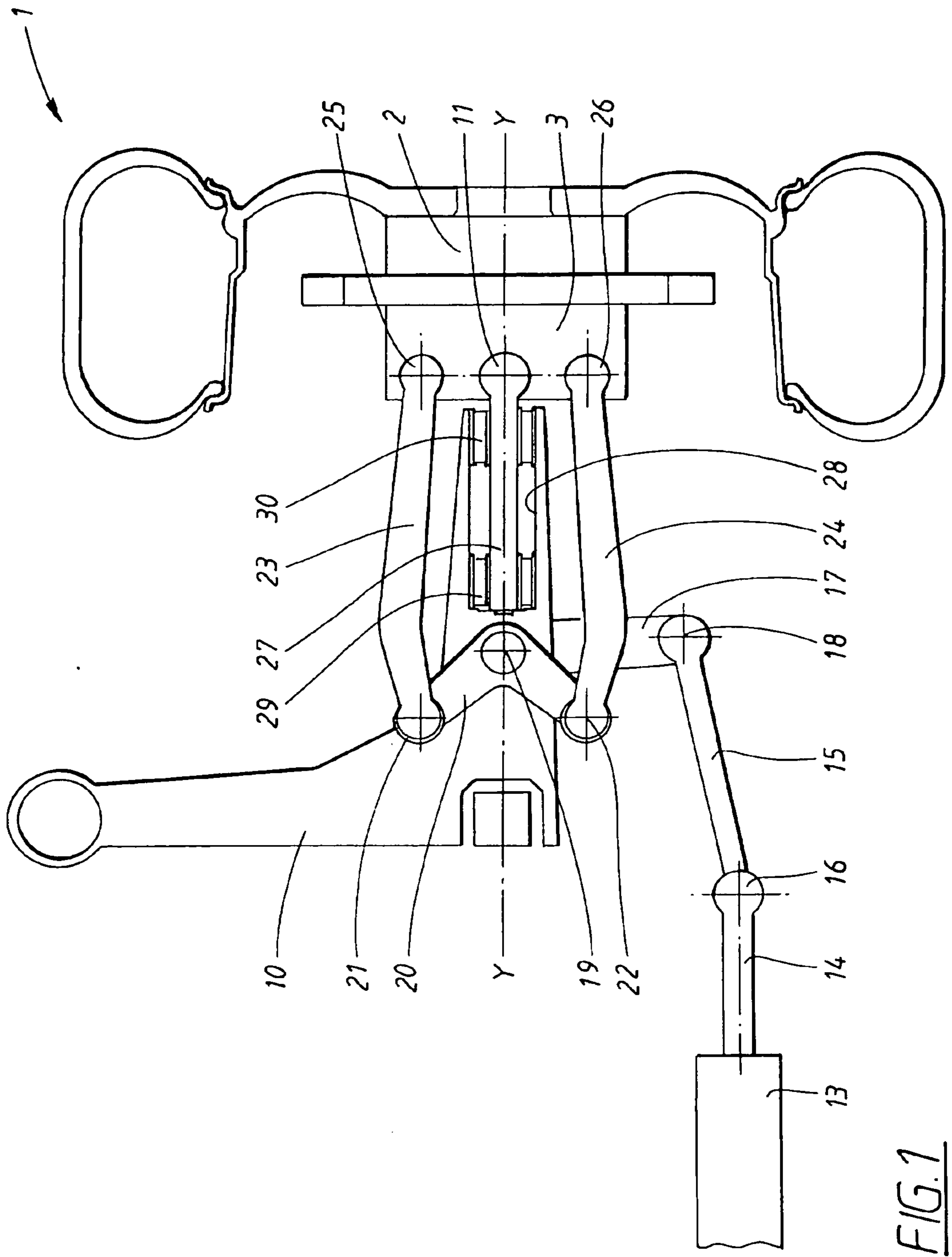


FIG.1

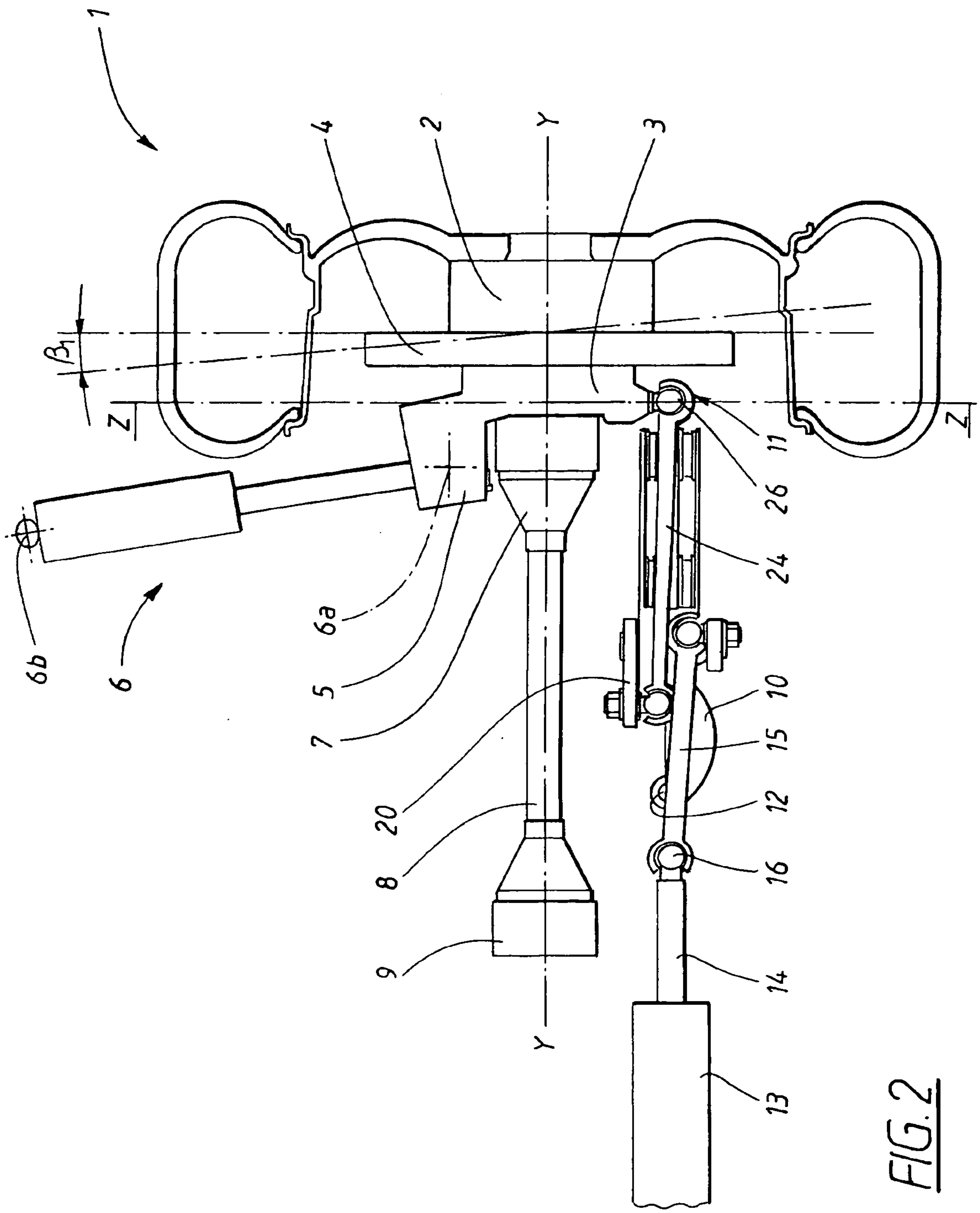
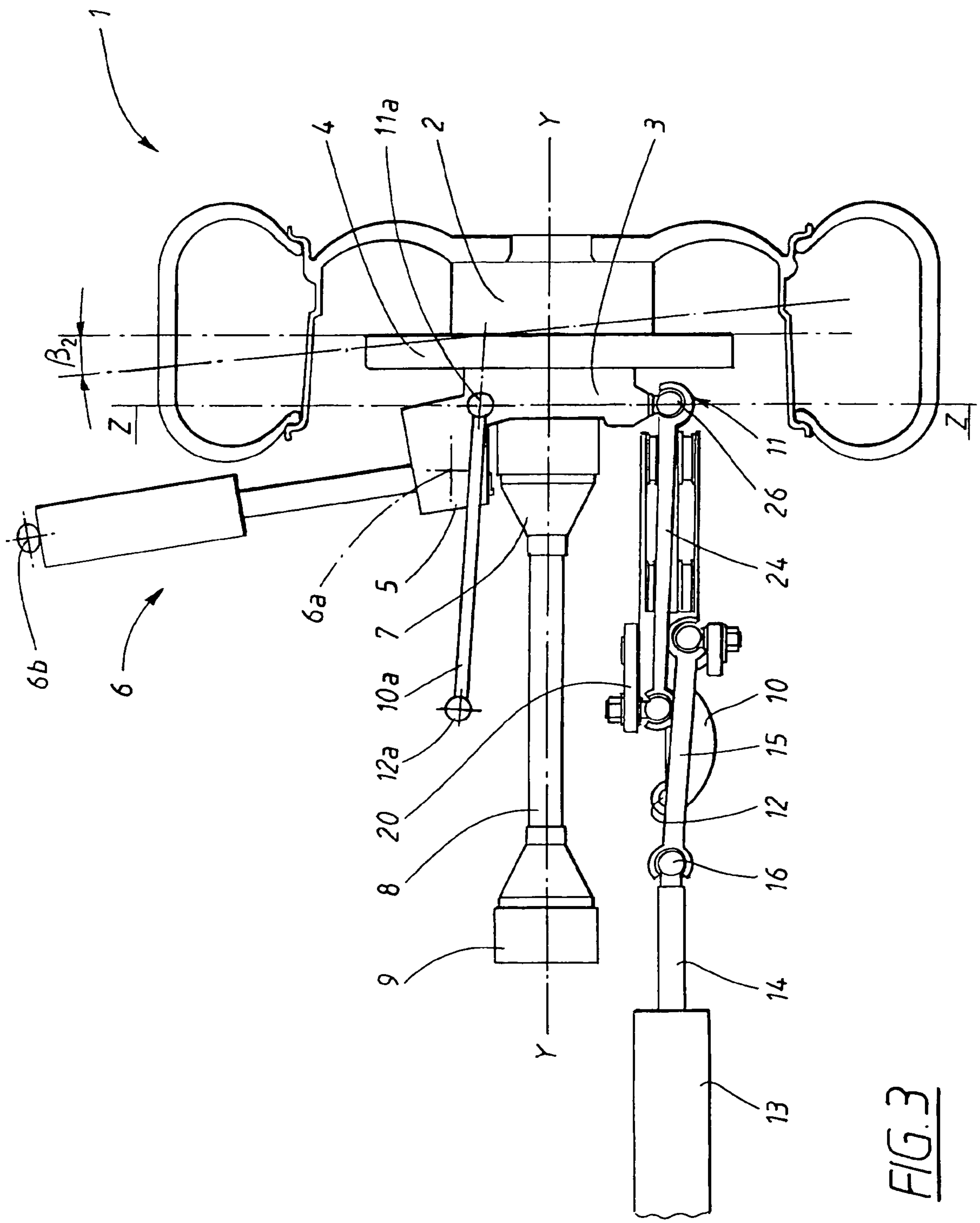


FIG. 2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6
6a
6b
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8
9
10
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11
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12a
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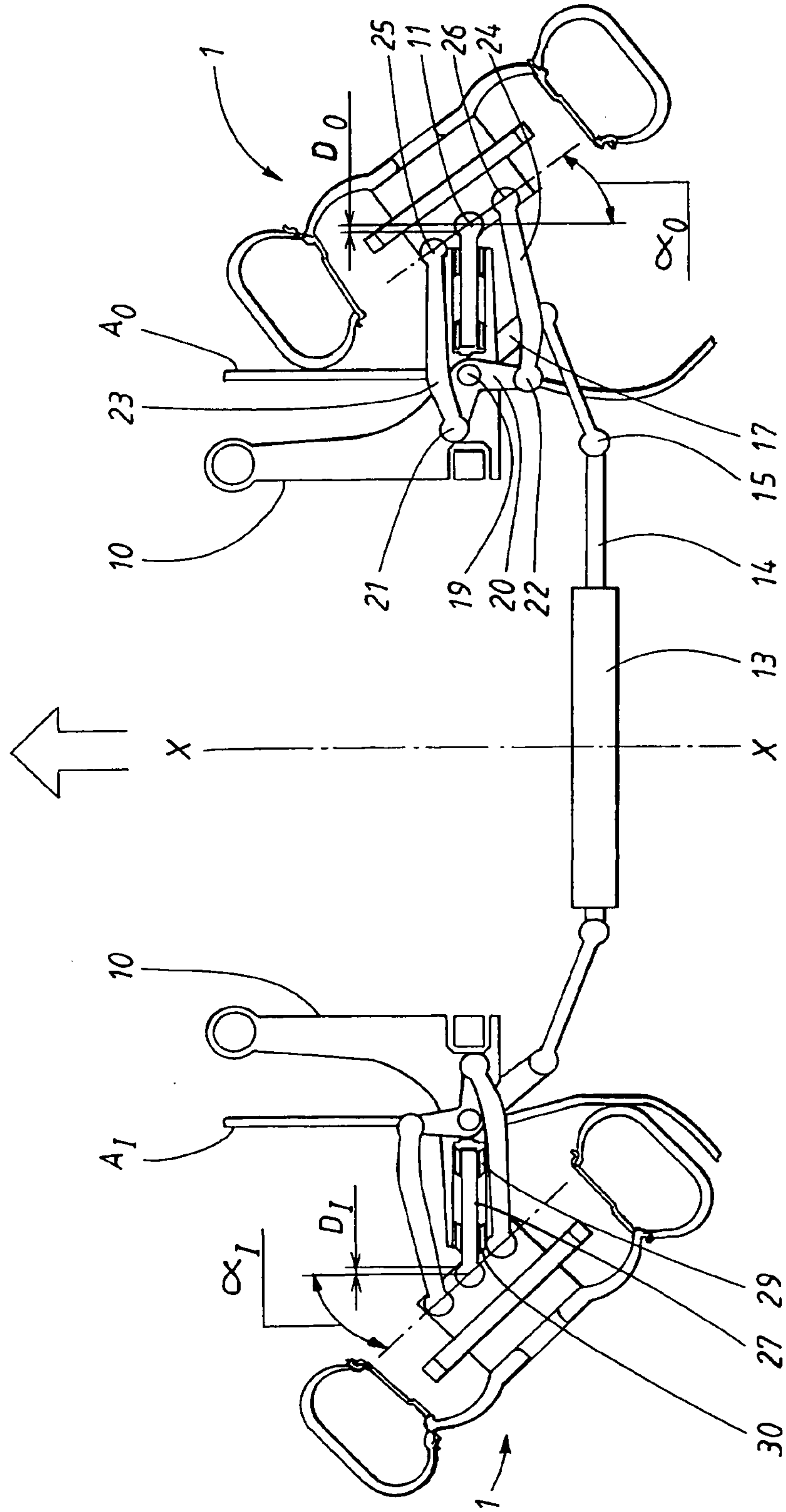
14
15
16
20
24
26
Y
Y
Z
Z
β_2

FIG.3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A_0
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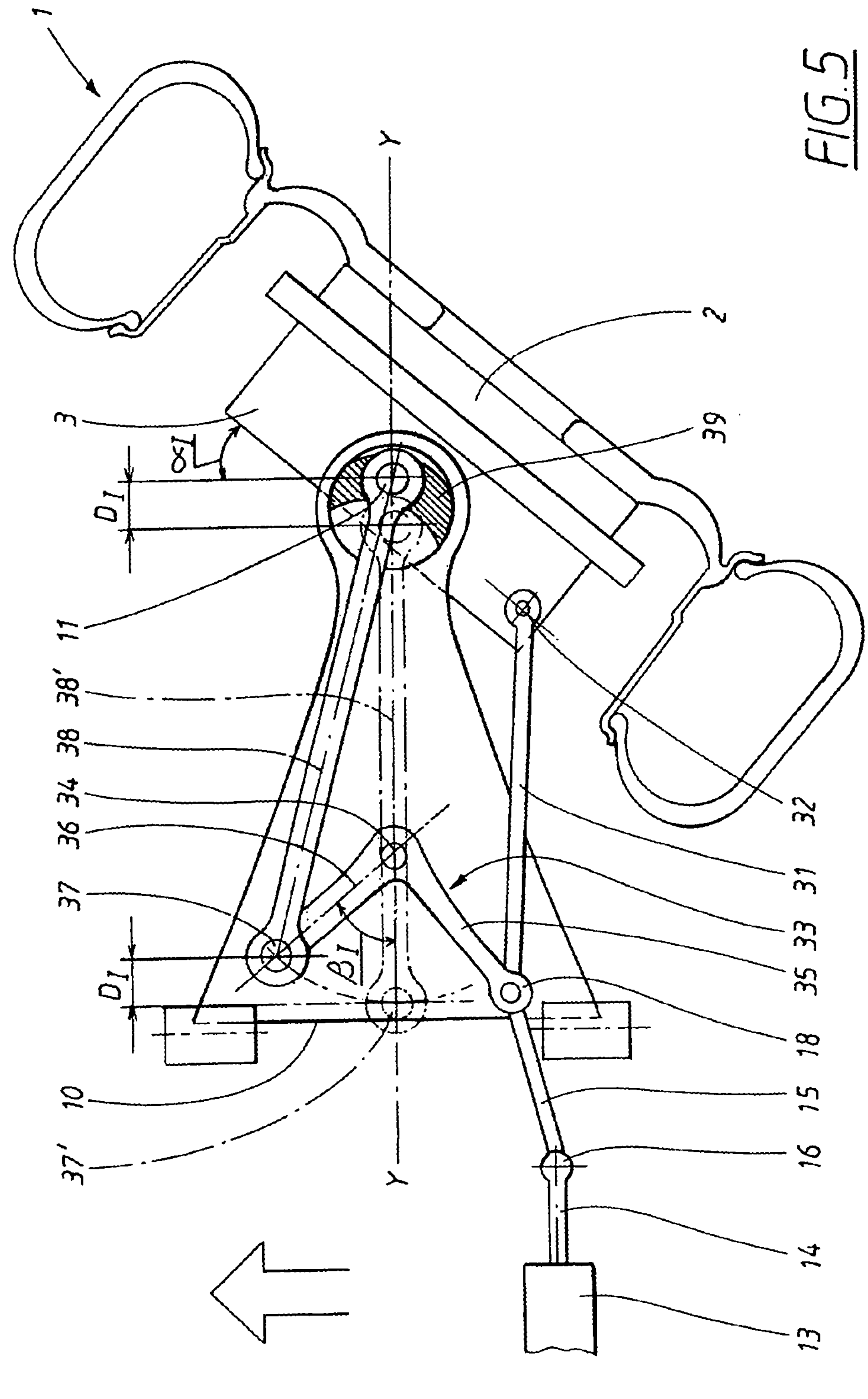
27
30
1

FIG.4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2
3
39
α_I
D_I
11
38'
38
34
36
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β_I
10
37'
Y
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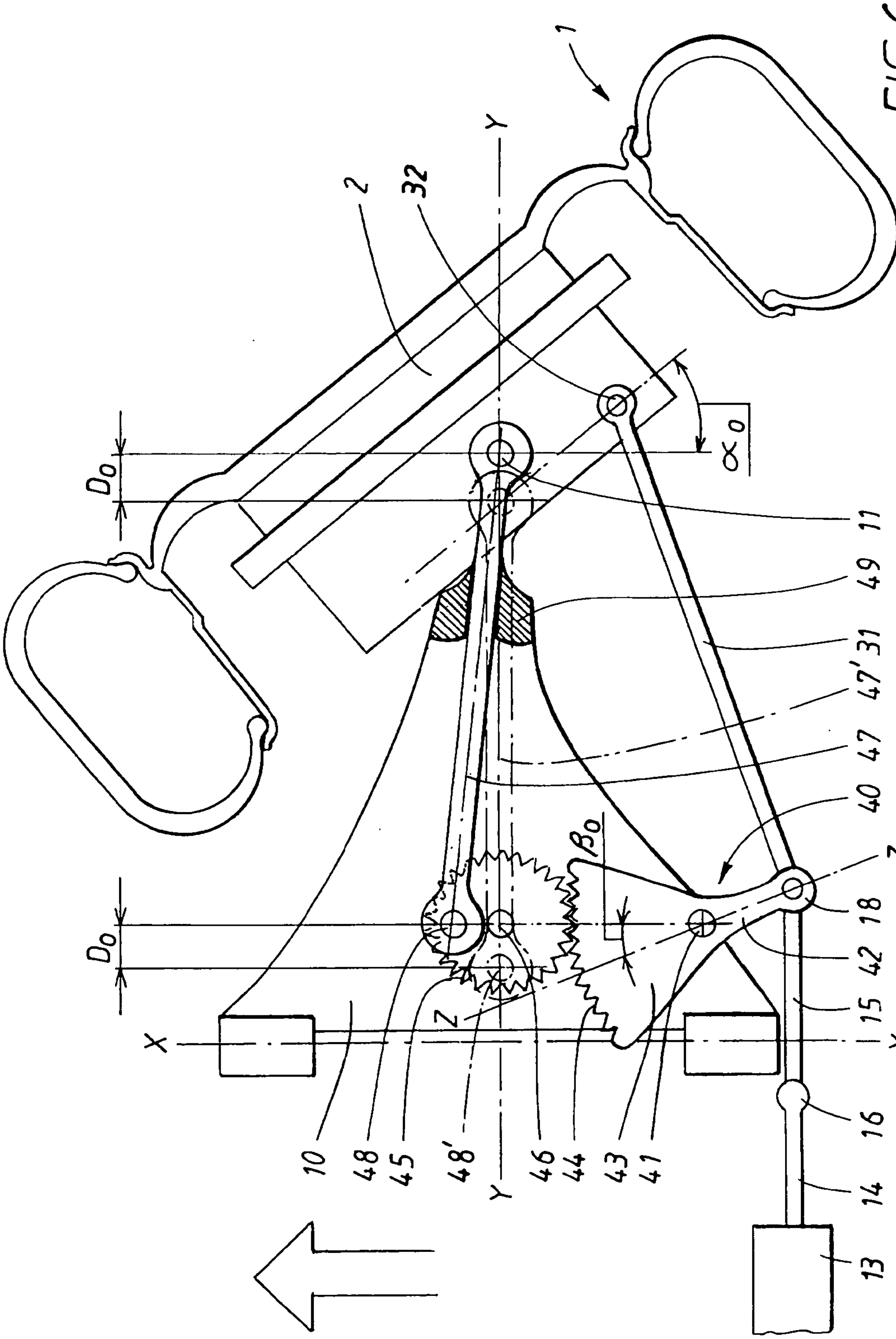
15
16
14
13

FIG.5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2
32
Y
D0
α0
11
49
31
47'
47
40
Z
18
42
15
X
16
14
13
β0
D0
X
10
48
45
48'
Y
46
44
43
41
Z

FIG.6

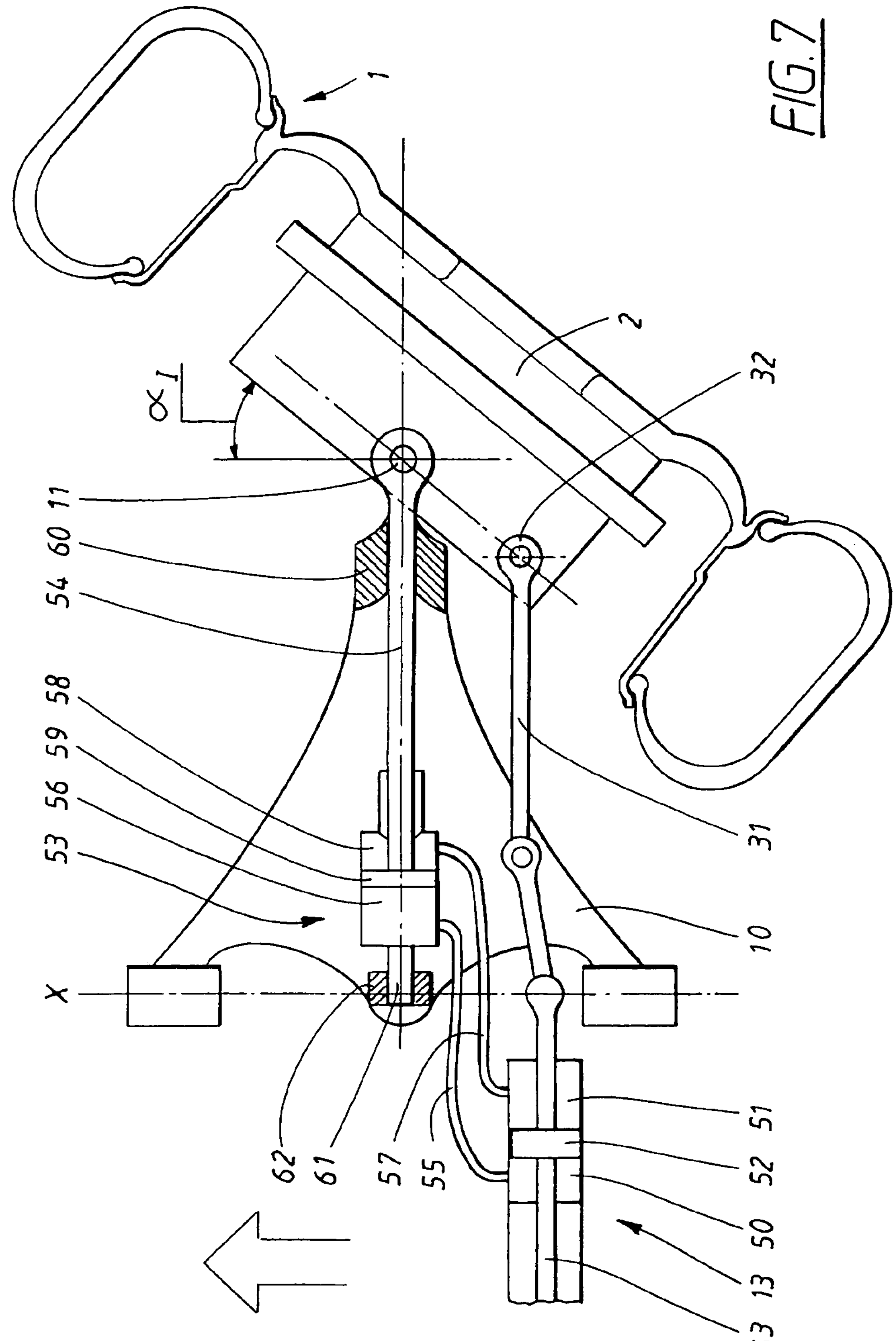

FIG.7

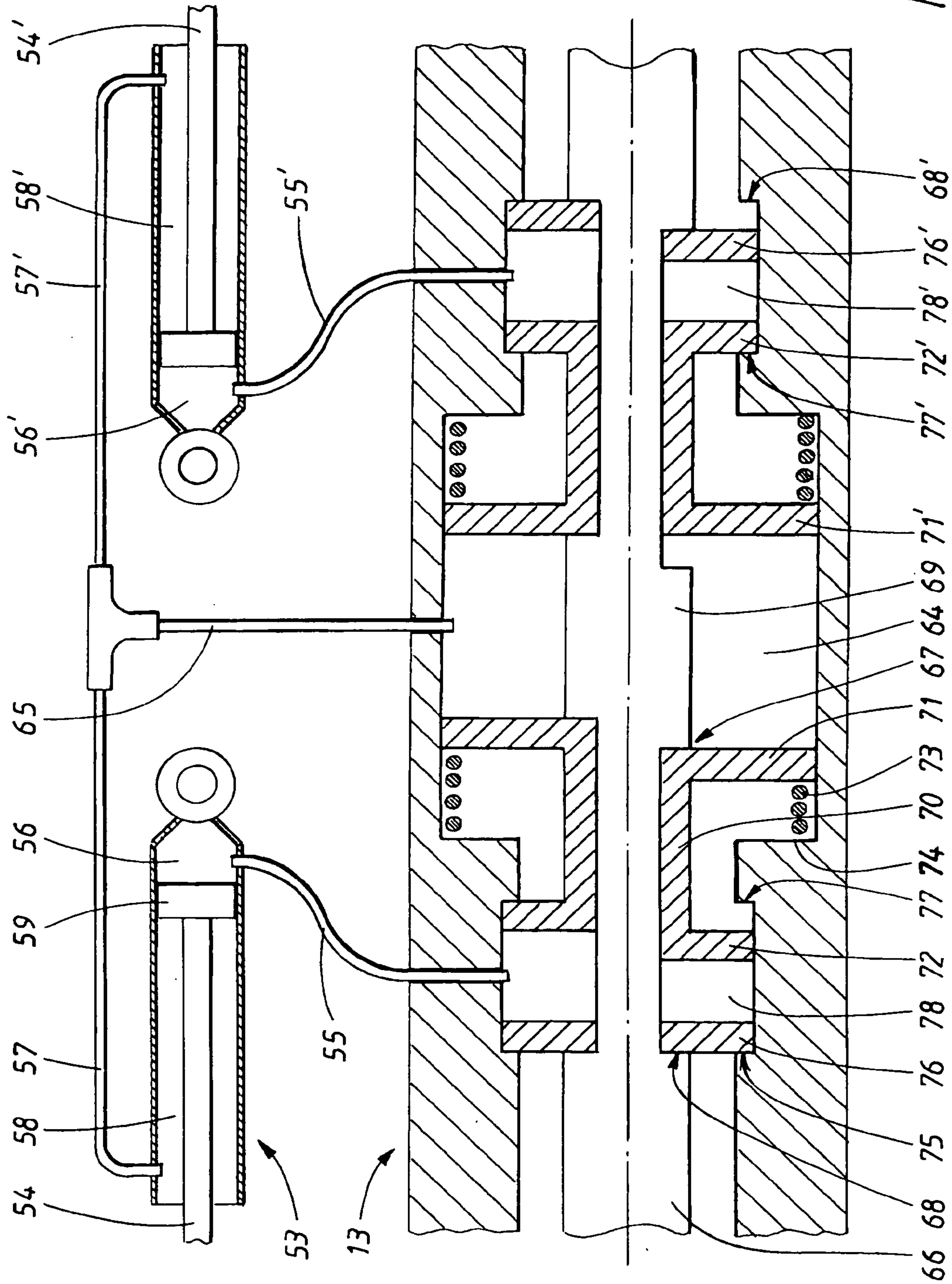
54'
58'
57'
55'
56'
65
56
59
55
57
58
54
53
13
68'
76'
78'
72'
77'
71'
69
64
67
71
73
70
74
77
72
78
76
75
68
66

FIG.8

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 02 44 5164

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X A	DE 37 36 229 A (DAIMLER BENZ AG) 22 September 1988 (1988-09-22) * abstract; claims 1,3,5-8; figures 1-4 * * column 1, line 56 - column 2, line 34 * * column 2, line 44 - column 3, line 16 * * column 3, line 50 - column 4, line 4 * -----	1-4,6-13 5	B60G3/20 B60G7/00
X A	US 3 587 767 A (GAMAUNT ROGER L) 28 June 1971 (1971-06-28) * abstract; claims 1-6; figures 1-3 * * column 2, line 18 - column 4, line 32 * -----	1-4,6-13 5	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			B62D B60G
	~~The present search report has been drawn up for all claims~~		

Place of search	Date of completion of the search	Examiner
Munich	4 April 2003	Balázs, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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European Patent Office

Application Number

EP 02 44 5164

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-13

European Patent Office

LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 02 44 5164

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-13

   Wheel track adjustment

   ---

2. claims: 14-29

   Suspension arrangement to absorb and dampen vertical movement of a vehicle wheel

   ---

3. claims: 30-44

   Steering linkage arrangement for controlling a vehicle wheel

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 02 44 5164

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

04-04-2003

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
DE 3736229	A	22-09-1988	DE	3736229 A1	22-09-1988
US 3587767	A	28-06-1971	NONE		

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82